The EWTES (Echo Range) Story

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In 1965, a U.S. Navy airplane was shot down over North Vietnam by a Soviet surface-to-air missile. Shortly thereafter, the Navy sought countermeasures and tactics that could mitigate this threat. It became apparent that tests of airplanes in the presence of threat simulators could provide many answers to tactical problems as well as enhance and complement countermeasure system design and development. The assemblage of simulation and range operations equipment that became the Electronic Warfare Threat Environment Simulation (EWTES) resulted from the combined efforts of several Navy in-house laboratories and numerous contractors. APL served as the system integrator under the direction of the Naval Air Systems Command. By July 1968, EWTES was operational with an initial threat simulator configuration that included the Fan Song B and Fan Song C. EWTES has proven to be a highly useful range for electronic countermeasure effectiveness establishment, radar homing and warning system testing, air vehicle radar cross-section evaluation, and tactics development and evaluation. (Keywords: Echo Range, EWTES, SAM system simulators.)

INTRODUCTION

In 1965, a U.S. Navy airplane was shot down over North Vietnam by an SA-2 surface-to-air missile (NATO code name Guideline; see Table 1). (The SA-2 is a Soviet-developed anti-air missile system that had shot down the U-2 high-altitude reconnaissance airplane piloted by Gary Powers on 1 May 1960.) Shortly thereafter, the Navy requested help from APL in developing electronic countermeasure and maneuver tactics that would mitigate this threat. The Laboratory was highly regarded as a unique resource of technical knowledge because of its expertise and experience in developing the Talos, Terrier, Tartar, and Typhon shipborne surface-to-air missiles and as a result of APL's evaluation of the missiles' shipboard search and fire control radar systems.

One of the Laboratory's responses to the SA-2 missile threat was to help establish a test program (CNO Project F/O 210) in which airplanes could be placed in a simulated threat environment. This simulated environment would permit analytically derived tactics to be tested in realistic situations. Sanders Corp. (now Lockheed Sanders) at Nashua, New Hampshire, had built a Fan Song B (SA-2B fire control radar) emissions simulator (Flintstone) using search radar components. The receivers and tracking subsystems of the simulator were not replicas of the Fan Song B because its original purpose was only to provide radiation to evaluate countermeasure system response. Therefore, Flintstone was not very representative of the threat, but it was the only simulator available at the time. It was decided to use this simulator and the associated facilities for initial F/O 210 tests.

The Navy's attack airplane evaluation squadron AIRTEVRON-5 or VX-5 (now known as VX-9) stationed at the Naval Weapons Center (NWC, now Naval Air Warfare Center, Weapons Division or NAWC WD), China Lake, California, was asked by Naval Air Systems Command (NAVAIR) to participate in F/O 210. VX-5 deployed two A-4 airplanes, pilots, and maintenance crews to the Manchester, New

Table 1. NATO code names for former USSR systems.

NATO code name	Former USSR designation	Function
SA-2B, C, E	V-75 Dvina	Surface-to-air missile system
Fan Song	(Not found)	Fire control radar for SA-2 system
Guideline	V-750	SA-2 system missile
SA-3	S-125 Neva	Surface-to-air missile system
Low Blow	(Not found)	Fire control radar for SA-3 system
Goa	(Not found)	SA-3 system missile
Fire Can	(Not found)	Anti-aircraft artillery fire control radar based on the U.S. SCR-584
—	Puazo 6	Anti-aircraft artillery optical fire control
Spoon Rest	P-12	Search radar usually associated with SA-2
Flat Face	P-15	Search radar usually associated with SA-3

Hampshire, airport. They also arranged with the Federal Aviation Administration for dedicated air space and provided an air controller to direct aircraft from the test site.

The Laboratory provided test control and data collection instrumentation and formed four teams to conduct the tests, with each team staying for 1 week at a time. Sanders provided the operators for the Flintstone as well as a Nike Ajax target tracker, which was used as a reference radar. The collected data were analyzed at APL, and results were reported to the Navy's Operational Test and Evaluation Force (OPTEVFOR).

The operations at Nashua began in September 1966, and after a few weeks of frantic upgrading and repairing of equipment and resolving procedural problems, the F/O 210 tests ushered in a period of relatively routine operations.

It became immediately apparent early in the F/O 210 program that testing airplanes in the presence of threat simulators could provide many answers to tactical problems, as well as enhance and complement countermeasure system design and development. This realization led to the proposition that a range equipped with instrumentation to test and evaluate countermeasures and tactics should be developed to provide a realistic threat environment. The Cold War situation in general and the Vietnam conflict in particular dictated that such a range should become available as soon as possible. Thus, the concept and consideration of an electronic warfare test range were started at about the same time as the conduct of the F/O 210 tests.

THE BEGINNING

Organization

The assemblage of simulation and range operations equipment that became the Electronic Warfare Threat Environment Simulation (EWTES) resulted from the combined efforts of several Navy in-house laboratories and numerous contractors. APL served as the system integrator under the direction of NAVAIR and, in this capacity, employed the following three mechanisms that contributed to the relatively fast initial development of EWTES:

1. The issuance of performance and compatibility requirements. These documents specified the requirements that defined the equipment and the environment under which they operated.
2. The establishment and direction of a design review task group consisting of all agencies involved in the planning of the range. This group provided the fast reaction necessary to resolve all types of situations that arose during the EWTES development.
3. The establishment and direction of a correlation task group consisting of all agencies concerned with the design of particular equipment. This group provided the opportunity for each agency to participate at an engineering level in the design of every mechanical and electrical interface involving that agency's equipment. All design agreements for each interface were documented on correlation drawings, which became the controlling elements throughout development.

The Laboratory pursued its responsibilities of system integrator by forming a team, led by Donal B. Staake, drawn from various groups, project offices (equivalent to the present program offices), and department offices. By early 1968, the need for a more formal organization was recognized and a project office (MM-4) was formed with the core team members and Staake as the supervisor (the author was his assistant). The team soon decided that it would be highly useful to have a permanent representative at EWTES to deal with day-to-day problems. Fred Crumbaugh, a 30-year Navy veteran who had retired with the rank of Commander, was hired for the job because he was thoroughly familiar with the EWTES infrastructure.

Location

The location of what was to become EWTES was one of the first considerations in its concept. Though several sites in the continental United States were suggested and evaluated, China Lake was chosen since it was an established test range, it had unrestricted air space usage within its boundaries, the weather was generally good for flight operations and employment of optical instruments, and VX-5 was stationed there. Furthermore, it was easily accessible by air from Edwards Air Force Base and Point Mugu Naval Air Station; the latter was the home station of VX-4 (now also part of VX-9), the Navy's fighter airplane evaluation squadron.

NWC's E ("Echo" in the phonetic alphabet) Range lies southeast of the main complex of China Lake. Randsburg Wash is a rather flat valley that extends from west to east in the center of Echo Range; the area of interest for the proposed operations was approximately 30 km (16 nmi) long and 10 km (5.4 nmi) wide. Echo Range was mainly used to test proximity-fuzed ammunition in the presence of airplanes suspended from wooden towers by nylon ropes. Since these tests would not interfere with the proposed EWTES concept, it was decided to locate the simulator at the western end of Randsburg Wash.

Component Development

During early 1967, the correlation task group began planning the EWTES operation control system, reference system, and initial simulator complement and configurations. An operational system was established as soon as possible.

Tasker Industries (Van Nuys, California) was building a set of Fan Song B and Fan Song C simulators for the Air Force. The company was placed under contract to build a set for use in EWTES. Each simulator had a Lewis scanner (to provide beam motion) and an antenna in the horizontal and vertical axes (essentially constituting two separate radars) mounted on a pedestal that provided motion in azimuth as well as elevation. The operator displays were as correct as was known at that time, and the radars were fully instrumented. The Fan Song B and C simulators could only be used one at a time since there was only one control van for both.

NWC proceeded to convert and instrument four SCR-584 radar vans to serve as Fire Can simulators. Along with these, they also built Puazo 6 simulators using pedestals from the Gun Fire Control System (GFCS) Mk 63 and optical system components from the Mk 28 Mod 0.

Under direction of the Naval Missile Center (Point Mugu), ITT Corp. (San Fernando, California) modified a surplus SPS-28 radar to simulate a Soviet Spoon Rest search radar. At the same time, they had a surplus TPS-1 radar modified by Vitro Services (Fort Walton Beach, Florida) to serve as a Soviet Flat Face search radar simulator.

General Dynamics, Pomona Division (now part of Raytheon Missile Corp.), designed and built an operations control system housed in a van. This system provided the displays and controls for the test conductor and his staff. At the same time, in conjunction with APL, General Dynamics assembled an instrumentation system into a van. This system served as the computing center for EWTES, performing such functions as processing, digitizing, and recording data. A program, using Fan Song radar data in real time, computed the performance of up to nine simulated Guideline missile intercepts and could be used off-line to establish intercept performance every second of a particular trajectory. This type of analysis could evaluate the usefulness of a specific tactic or electronic countermeasure.

During the planning stage, it became clear that the Guideline missile intercept performance could not be properly evaluated unless a reference system with minimum errors was used. This could only be accomplished by reference tracking the target within the Fan Song radar. To address this problem, the Laboratory built pods (aerodynamic and mechanical design by Don Michaud and electronic configuration by Steve Partin) to be carried externally on aircraft. Each pod contained beacons that received the L-band missile uplink commands and replied at S- or C-band depending on which simulator was being used (see Fig. 1). They also carried X-band beacons to augment the tracking capabilities of the reference tracking radars. Up to four aircraft could be beacon-tracked in a Fan Song simulator. Five pods were built and installed in a dedicated van along with test equipment and spare parts. The van was driven to NWC and stationed at VX-5 to provide pod installation maintenance service.

M-Tech Corp. (Pomona, California), working for NWC, modified components of surplus Nike fire control systems to serve as target reference trackers.

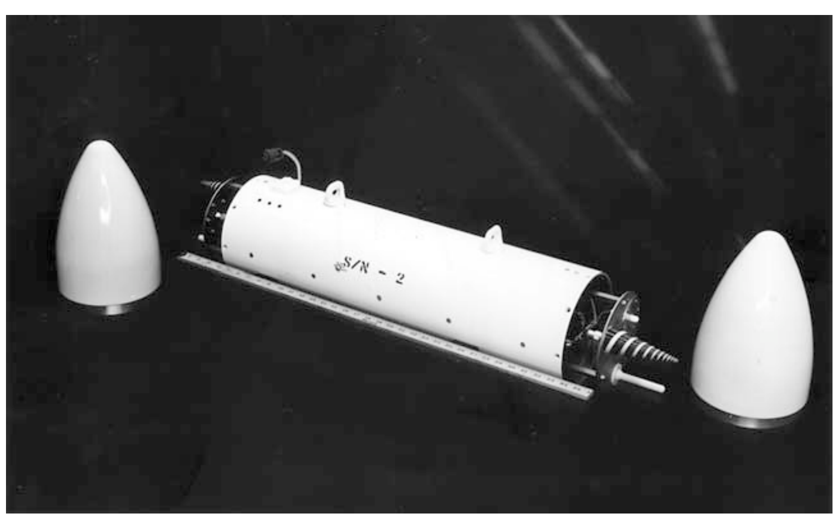

Figure 1. Beacon pod with radomes removed to show antennas.

A surveillance radar, two tracking radars equipped with boresighted TV cameras, and a control van comprised the system; the radars provided general air surveillance for safety and for the test conductors to identify and vector-test the aircraft. The radar system also served as the aircraft position reference if the beacon reference system was jammed or inoperable.

Initial Range Configuration

By July 1968, the EWTES was in operation and consisted of the Central Site complex (Fig. 2) with the Fan Song B and C simulators, the Spoon Rest simulator, the operations control van, the instrumentation van, a Nike surveillance radar and reference trackers, and several auxiliary vans. There were also two remote sites, each equipped with a Fire Can simulator and a Puazo 6 simulator.

As air operations began it was immediately apparent that the careful planning and hard work put into the project by all concerned were paying off; EWTES was highly effective in performing the task for which it was designed. The experience gained during F/O 210 had helped tremendously in the planning and development of EWTES.

EWTES FROM 1968 THROUGH 1972

Additions to EWTES were being planned even as initial F/O 210 operations were being conducted. The simulators for two surface-to-air missile system fire control radars, Fan Song E and Low Blow, were added in this period.

Figure 2. Initial EWTES configuration (circa June 1968).

Fan Song E Simulator

The SA-2E had appeared in the Soviet Union in the early 1960s and was considered a formidable threat.[1] The Fan Song E, the fire control radar for the SA-2E, had two large paraboloidal antennas mounted above the Lewis scanner antennas, thus providing a smaller scanning area. This configuration resulted in more accurate angular tracking and greater range capability (due to higher gain) than the earlier versions of Fan Song. It also operated at C-band as opposed to S-band for the Fan Song B. In the summer of 1968, the Laboratory undertook the task of building a Fan Song E simulator. Requests for proposals were prepared and sent out. The contract was awarded to Tasker Industries, which was well experienced in this area.

The Laboratory, through MM-4, participated extensively in the design of the system. One of the factors involved in the design of simulators in general and the Fan Song E in particular was the lack of detailed knowledge in large areas of the original design. For example, the knowledge gained by analyzing the emitted waveforms could not reveal the receiver noise figure or the counter-countermeasure logic that might have been built into the system. At this point, the program had to depend on the large experience base and analytical foresight of people like Don Staake to fill in the information gaps with reasonable and logical deductions. Staake's deductions were proven to be considerably accurate after the actual equipment was exploited and described by intelligence agencies.

Additionally, it was known that the Soviet designers were using vacuum tubes in their circuits. For reliability and ease of maintenance, solid-state circuitry was used in the simulators to the greatest extent possible. Furthermore, commercially available components rather than uniquely designed circuits were used wherever possible. For example, intermediate-frequency amplifiers with the appropriate gain and bandwidth were purchased essentially off-the-shelf for use in the Fan Song E simulator receiver. This substitution philosophy led to simulators that were functionally the same as the original systems but different in their internal circuitry.

By February 1970 the Fan Song E was in place at the Echo Range Central Site (where it remains to this day). The Fan Song C simulator was taken out of service because it was redundant but was retained for spare parts.

Low Blow Simulator

Figure 3. Low Blow simulator antenna system.

The SA-3 was deployed in the Soviet Union by 1961 in "static" sites.[1] Little was known about it at that time other than its emission characteristics and its components' physical appearance. By 1968 it was deployed in Egypt and was used in combat during the 1970 Egyptian–Israeli war; five Israeli F-4E Phantoms were shot down by SA-3s.

The SA-3 system consists of the Low Blow fire control radar, the Goa surface-to-air missiles and associated launching system, and the Flat Face acquisition radar. As with the SA-2, a command guidance scheme is used to bring the Goa to intercept the target. The Low Blow is quite different from the Fan Song in that it transmits a beam from its one paraboloidal antenna and does scan-on-receive-only with its two scanning antennas. The scanning antennas are set at 45° from the traverse and elevation planes. Furthermore, the transmitter frequency for Low Blow is X-band, while the Fan Songs are S- or C-band, depending on the version.

By January 1970, the Laboratory proceeded with a plan to construct a Low Blow simulator. The Georgia Technological Research Institute—selected owing to its overall excellence and reputation of creating "one-time" units at a reasonable cost—designed, built, and mounted the antenna and transmitter systems on a pedestal. The Laboratory designed and built the receivers, radar controls, and displays, and provided the control and data collection computers. Except for the front end of the receiver, all these parts were housed in a van, with a "best guess" based on the SA-2 as to the control and display configuration. Figure 3 shows the Low Blow simulator antenna array when it was first installed for EWTES. The box at the end of the trailer contains the transmitter modulator, while the transmitter and receiver front end (a low-noise traveling wave tube) are contained in the antenna array as close to the antennas as possible to minimize losses.

A clever innovation in the receiver design was conceived by Ken Tritabaugh of MM-4. Instead of using the automatic gain control voltage to adjust the receiver gain directly, it was converted to binary numbers controlling an array of attenuators at the input to the intermediate-frequency amplifier. The array was set to provide up to 64 dB of attenuation, and the binary number was recorded as a decibel value. This practice provided a simple method for reading the target return power level when analyzing test data. This scheme is used in some radars today, but 30 years ago it was an imaginative approach.

There had been much speculation in the threat assessment community as to whether the Low Blow receiver had a Moving Target Indicator (MTI) system. MM-4 decided to design and build a three-pulse canceller digital MTI that could be switched in or out of the Low Blow simulator receiver as desired. Analog MTI systems had been in use for 20 years or so by then but were not very reliable because of the inherent instability of the phase measurement circuitry. By the late 1960s, analog-to-digital converters with sufficient speed and bandwidth had been developed such that the input pulses to an MTI system could be digitized, thus numerically characterizing their amplitude and phase. These numbers could then be manipulated to determine the applicable cancellation on a pulse-by-pulse basis. It was determined a year or two later that the Low Blow radar receiver indeed had an analog MTI feature and that its performance, when working properly, was simulated by the digital MTI.

The Low Blow simulator was delivered for EWTES by early August 1972. It was located at a site approximately 2 miles to the south of the Central Site; the Flat Face simulator had been located there since October 1970.

1972 EWTES Configuration

By October 1972, EWTES consisted of the following:

- The Central Site complex, which comprised the Fan Song B and E simulators (each operating

independently), the Spoon Rest simulator, the operations control van, the instrumentation van, the Nike surveillance radar and reference trackers, and several auxiliary vans.
- A remote site where the Low Blow and Flat Face simulators were located.
- Four remote sites, each equipped with a Fire Can simulator and a Puazo 6 simulator.

By this time, the reference beacon design had been modified to reply to the various threat radar simulators. This modification was incorporated into a new set of reference beacons by Vega Precision Laboratories (Vienna, Virginia) under APL's direction.

Application of Test Results

Early EWTES tests led to the development of countermeasure tactics used in North Vietnam. These comprised the combined use of jammers (AN/ALQ-51 and AN/ALQ-100), chaff dispersal, and maneuvers (primarily the split S dive) for defeating command-guided surface-to-air missile systems. The tactics were reputed to have saved many lives in the air raids against defended installations. It is difficult if not impossible to quantify the degree of success achieved by these tactics, but anecdotal evidence suggests that the benefit of EWTES was very high.

MM-4 Disengagement from EWTES

By the end of 1972, NAVAIR decided to transfer the acquisition of further assets for EWTES to NWC, thereby eliminating the role of MM-4. The Laboratory was still involved in EWTES because F/O 210 was ongoing. The MM-4 and other associated personnel regretted the transition because the development of EWTES had been an absorbing technical and temporal challenge. Furthermore, it was an opportunity to enjoy the best aspects of teamwork with people of formidable technical competence and experience. In mid-1973, the Fleet Systems Department underwent a reorganization, resulting in the incorporation of MM-4 into the F3 Branch under Don Staake.

EWTES TODAY

EWTES has evolved and grown enormously since 1972. As an example, there are now several sites equivalent to the Central Site: Land Site 1 (formerly the Central Site), Land Site 2, Sea Site 1, and Sea Site 2. There are also many individual sites—some located for convenience and others for specific purposes. The use of EWTES by the services (and by NATO forces) has expanded over the years and continues today. It has proven to be a highly useful range for the testing of electronic countermeasure effectiveness, radar homing and warning system testing, air vehicle radar cross-section evaluation, and tactics development and evaluation. It is obvious that EWTES is an important and highly useful national defense asset and will continue to be so in the future.

REFERENCE

[1] Cullen, T., and Foss, C. F. (eds.), *Jane's Land Based Air Defence*, Seventh Ed., Jane's Information Group, Inc., Alexandria, VA (1994–1995).

THE AUTHOR

ARTHUR C. WILLIAMSON joined the Laboratory in 1956 after receiving a bachelor's degree in physics from the Illinois Institute of Technology (1954) and serving in the U.S. Army (1954–1956). He has pursued graduate courses at the University of Maryland, Catholic University of America, and The Johns Hopkins University (1956–1970). His experience includes testing of guided missiles and radars, evaluation of air defense systems, design of radar and instrumentation components, interpretation of radar and guided missile intelligence, and program management. Mr. Williamson was appointed to the Senior Staff in 1960 and to the Principal Professional Staff in 1974. His e-mail address is arthur.williamson@jhuapl.edu.